

White Paper Report

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1. Cover Page

WHITE PAPER

Grant Number PF-50087-10

Title of Project: Improving Environmental Conditions for Historical Collections

Project Director: Ann Lawless

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**American Precision Museum
Sustaining Cultural Heritage Collections project—White Paper**

Narrative

a. Project Activities

Our project goal at the American Precision Museum, Windsor VT, was to bring together a team of consultants to work with staff and two representatives from our Board of Trustees to develop a plan to address moisture conditions adversely affecting the building and collections. All our consultants participated as planned – Mr. Tom Keefe, preservation architect, Mr.



Bob Neeld, structural engineer, Mr. Dan Dupras, mechanical engineer, and Mr. Rick Kerschner, conservator. Due to changes on our Board, only one trustee participated, Mr. Blaine Cliver, who is very well qualified, being a retired preservation architect and formerly director of the Historic American Engineering Record program. Mr. Keefe arranged a walk-through with the engineering consultants, at no cost to the project, to familiarize themselves with the building prior to the first official project team meeting. That meeting was held on December 16, 2011. Mr. Kerschner toured the building and off-site storage areas with Mr. Keefe during the morning before we sat down for the team meeting. Prior to the meeting, staff had provided digital access to our temperature and humidity monitoring information at www.PEMdata.org, and also shared with all team members a variety of reports about the building and collections.

We worked closely with Mr. Kerschner as to whether he should include in his recommendations the very low impact approach (option E) that he proposed. That is to leave conditions as they are now (no climate-control) on all the upper floors, provided we first isolate the basement moisture and create the “room within a room” for the archives and most vulnerable composite artifacts such as the firearms. We determined we should include that option as it is the most practical and cost effective plan.

b. Project Accomplishments

Following the Dec. 16 meeting, the consultant prepared draft reports for their respective areas of expertise, and those were shared among all the participants. We followed up with a conference call on February 18, 2011 to bring the report details into alignment, reduce redundancy, and in order to make the reports useful for raising the funds needed to proceed with the plans. The final consultant reports from Mr. Neeld, Mr. Kerschner and Mr. Keefe are attached, along with a printout of the photos that Mr. Kerschner included on a CD. Mr. Neeld’s findings were not lengthy or complex enough to merit a separate report. Therefore Mr. Keefe incorporated those findings into his own report, which is meant to be read as a summary of the entire project. The reports were completed in late February 2011, much earlier than anticipated. We asked the consultants to prioritize their recommendations, and they did, into both short term and long term projects, listed in Mr. Keefe’s report. After completing the first priority item

immediately, we submitted a proposal to NEH Preservation Assistance grant program to fund the next short term items. Award notification is pending.

One of the most significant results of the project was the staff learning opportunity provided through working directly with the consultants. Mr. Kerschner is extremely practical and sensible, and he made several suggestions to help us negotiate between the perceived visitors' needs to fully experience the authenticity of our water-powered mill site, and those needs related to long term artifact preservation. He suggested we create a small label to encourage visitors to open one of the window blinds to view the adjacent Mill Brook that originally powered the Armory in the 1840s, and then carefully lower it to protect against light damage.

Mr. Kerschner observed that most of our artifacts, the machine tool collections, are very hardy and can relatively easily be protected from surface rust by the application of coatings – a project we began several years ago. Recognition boosts morale, inspires confidence, and provides encouragement to do more.

c. Audiences

The main audience for the project was internal. We did not plan to have formal presentations by the consultants to the museum's Board of Trustees. However, we decided to put the team's recommendations on the agenda for our annual Board of Advisors meeting, held on June 14, 2011. Several trustees were in attendance. The reports by Mr. Keefe and Mr. Kerschner were included in the pre-meeting packets. Twenty advisors, five staff and three Trustees attended. We contracted with Mr. Keefe and Mr. Kerschner to lead the morning agenda. Mr. Kerschner opened with an introductory fifteen minute slide presentation, then he and Mr. Keefe led a walk through of the Armory second floor storage, main floor exhibit, and basement areas. They fielded questions from the group over lunch. The afternoon discussions focused on fundraising for the project priorities, along with other museum fundraising needs, sustaining the operating budget, and exhibits planned for 2012-12 and for 2014.

The reports and list of priorities will be presented to the Board of Trustees at their meeting July 21, 2011, and integrated into strategic planning. Thanks to NEH, the audience for this project is national. We appreciated being selected as a model application, with our application narrative posted as a sample project.

Elizabeth Joffrion, NEH Senior Program Officer, invited Mr. Kerschner and me to serve on a panel she is chairing at the American Association for State and Local History (AASLH) conference in September in Richmond VA on Friday, September 16, 2011, called "Sustainable Preservation: Balancing Collections, Resources, and the Environment." Although Mr. Kerschner will not be able to attend, he has promised to help me prepare the presentation. Although we spent all the grant money as planned and there are no funds left over, the museum is planning to cover my travel expenses.

d. Evaluation

We did not conduct a formal evaluation as part of the project. I include the following anecdotal comments from members of the Board of Advisors. These comments were provided via email or in conversation with staff:

- It was a terrific meeting. I was very interested to learn about the Aspiring Smoke Detection (ASD) system.
- It was a great meeting. I would have liked it if the afternoon fundraising discussion had focused more on the fundraising strategies for this project rather than integrating it with the museum's other financial needs.
- As a new member, I appreciated the opportunity to learn so much about preservation and conservation issues - things the general public doesn't usually think about.
- One new member of the Board of Advisors expressed his support with his pocketbook, by contributing an unrestricted gift.

e. Continuation of Project

Our consultant team all expressed the desire to follow up and be involved in the next steps. I was surprised that both Mr. Kerschner and Mr. Neeld said they are seldom called back to see the results of their recommendations put into place. They both welcomed the opportunity to do so at our museum. Mr. Kerschner urged us to think in terms of a multi-year, multi-phased implementation project with built-in periodic assessments. Mr. Kerschner recommended that we build in some assessment and evaluation of a year's results once the proposed mini-splits have been installed on the 1st floor.

We plan to apply to seek implementation funding – appealing to grant sources, individual and corporate funders.

f. Long Term Impact

Because Mr. Keefe is so familiar with our building, not only its preservation but also its programmatic needs, he was able to incorporate those issues into the list of priorities. This “big picture thinking” makes it much easier to present the case to Trustees and funders who may be more inclined to think about exhibits and programs and be less aware of professional standards in museum collections care or preservation issues in historic buildings.

As we had hoped it would, our project reports can provide a blueprint for action that will enable APM to preserve the artifacts and historic building for generations to come. The project has generate a self-awareness and confidence that will form a strong foundation for raising the necessary funds to implement the plan.

g. Grant Products

All grant products are included in the Appendices.

Report by Mr. Kerschner, with printout of his photographs

Report by Mr. Keefe

Report by Mr. Dupras

**Environmental Improvement Report
American Precision Museum**

NEH Sustaining Cultural Heritage Planning Grant Project

February 20, 2011

Site Visit December 16, 2010

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1. Introduction

The consultation was conducted on December 16, 2010, as part of an NEH Sustaining Cultural Heritage Planning Grant. From 9:00 to 11:30, I toured all four floors of the Armory building, the Annex storage building, and the large machine storage area at the Windsor Technology Park with Collections Manager Beau Harris. I also reviewed the past 6 years of temperature and humidity data for all three buildings accessible online at PEMdata.org. From 11:30 to 3:00 I met with other team participants that included Executive Director Ann Lawless, Collections Manager Beau Harris, Collections Technician John Alexander, Consulting Architect Tom Keefe, Consulting Engineer Bob Neeld, Consulting HVAC Engineer Dan Dupras, and Board Member Blain Cliver. The afternoon was spent discussing mainly how to improve the environmental conditions for the collections contained in the American Precision Museum Armory building.

Artifacts in all three buildings appear to be in generally good condition. The collection consists primarily of two types of artifacts: metal machinery and paper library and archive documents. Other types of material do exist, such as painted and natural wood and leather and a large oil painting in the Armory Lobby, but these materials are in a small enough quantity that they should not dictate environmental conditions for the greater collection. cursory observation of artifacts did not reveal significant deterioration problems with the exception of a few painted metal machines that are actively flaking paint and several heavily rusted machines that were stored in the damp basement. Fortunately, these machines were being removed to a safer storage area by riggers the day of the meeting. There was no evidence of mold growth from high humidity conditions in collection exhibit or storage areas. For more detail on the condition of collection artifacts, see conservator Clara Deck's 2008 NEH Preservation Assistance Grant report.

A **Summary of Recommendations** is attached to this report as **Appendix 1**. Photographs of the space taken during this visit are included on the photo CD that accompanies this report.

(A) Goal

The goal of this consultancy is to advise on environmental improvement methods to preserve collection artifacts especially by reducing high relative humidity levels (over 65%) that could accelerate corrosion of metals and by increasing low relative humidity levels (below 35%) for the paper archival documents. There is interest in accomplishing this goal by installing and operating new low-cost practical environmental control systems.

(B) Preventive Conservation Online Manual

Supporting information for many of my recommendations can be found at the Canadian Conservation Institute's *Conservation Resource Center*

<http://www.cci-icc.gc.ca>

To better understand this report, I recommend reading *Ten Agents of Deterioration* located on the right sidebar of the CCI homepage. Start with Chapter 9, *Incorrect*

Temperature, and Chapter 10, *Incorrect Relative Humidity*. All ten chapters are informative and useful, and they are listed in general order of the extent of damage that they cause to collection artifacts. In conducting risk management for your collection, address those agents higher on the list first.

2. Recommended Temperature and Relative Humidity Ranges

Although ideal museum temperature and humidity guidelines for general collections are $68^{\circ}\text{F} \pm 3^{\circ}\text{F}$ and $50\% \text{ RH} \pm 5\% \text{ RH}$, such stringent conditions are difficult and expensive to maintain even in specially designed and newly constructed buildings. It is nearly impossible to maintain such conditions in a historic building such as the Armory. Furthermore, maintaining 50% RH in a historic building during cold winter months can result in condensation on interior windows and walls, promoting mold growth and eventually causing damage to the building structure. The large majority of artifacts in historic building museums are safe within much wider temperature and humidity ranges.

The elimination of relative humidity extremes above 70% and below 25% is a practical and safe goal for the preservation of historic collections (see tables in “Incorrect Relative Humidity” by Stefan Michalski on CCI website). Mold will not form and corrosion of metals will be held in check if RH is usually kept below 65% and does not exceed 70% for more than 3 or 4 days in a row. Low humidity is not a problem for metal artifacts, but very dry conditions below 20% RH for extended periods of time must be avoided to prevent paper archives from drying out and becoming brittle, paintings on wood and canvas from cracking and flaking, wide boards in building and wood furniture from splitting, and veneer from de-laminating from furniture. **A seasonally adjusted RH range of 35% in the winter to 65% in the summer should be safe for preservation of your collection of largely metal and paper artifacts, as long as the RH is ramped between these extremes with seasonal changes.** These are the RH levels that the environmental control system should be designed or modified to maintain.

Temperature settings in museums that are open year-round are usually determined by human comfort requirements. Temperature is less critical for artifact safety except as it affects relative humidity. Cold temperatures do not harm most artifacts. In fact, since chemical reactions that cause deterioration proceed at a slower rate at lower temperatures, cold storage extends the life of organic artifacts. For every one degree Fahrenheit the temperature is reduced, the RH will increase by about 1.4%. Therefore, a heated space that is at an unsafe 20% RH at 70 °F could be increased to a safer 35% RH by simply reducing the heat to 58°F. Conversely, a relative humidity of 80% in a space cooled in the summer to 72°F will decrease to 66% if the space is cooled to only 80°F. Of course, if you heat the building less in the winter or cool it less in the summer, energy costs will also decrease. Since the American Precision Museum is closed from November through May, it is not necessary to heat 90% of the Armory building where the collection artifacts are exhibited or stored for visitor comfort. This is fortunate since it would be very expensive to heat this large, uninsulated building to comfort levels for even part of the cold seasons.

(A) Proofing – An important factor affecting the preservation of collection artifacts made from organic materials in most historic building museums in Vermont is the fact that they have been subjected to relative humidity levels above 70% and below 25% for extended periods of time over the past 100 years. This is actually good news, because it means that the artifacts have been “proofed” to a relatively broad RH range. Any damage caused by very dry winter conditions or very humid summer conditions has already occurred (see Chapter on “Incorrect Relative Humidity” by Stefan Michalski on the CCI website). Your collection of large metal artifacts does not really benefit from proofing because inorganic materials do not change dimensions with changes in temperature and humidity to any significant extent, and they will still continue to rust if the RH is too high. Probably the main artifact in your collection that has benefited from proofing is the large painting on canvas in the Armory lobby that must shrink as it dries in the winter and expand during the summer. Eventually these extremes may cause the paint to crack and flake from the canvas, but to date it appears to be in good condition.

One caution – conservation treatment of an artifact resets the “proofing” clock. When a damaged artifact such as the table with the crack in the top is conserved and the crack is glued together, new stresses can be set up in the wood and it may crack in a different place if again exposed to low humidity conditions. However, a good conservator should be able to treat the artifact so that it will be resilient through a relatively wide relative humidity range. Often this means making sure the original construction works, i.e. wide wood panels float freely in a frame to prevent cracking when the wood swells and shrinks in response to the changing environment.

(B) Preventing Condensation and Flash Rust – Large metal artifacts exhibited or stored in an unheated space can be in danger of moisture condensing on the cold metal surface when warm, moist air enters the space, usually on an early spring day. Water condensing on the surface of an iron or steel artifact can cause flash rust very quickly. There is little evidence that this has happened at the APM, but it could in the future if the weather changes rapidly and warm air infiltrates the building while the metal artifacts are still very cold. Fortunately, such condensation is relatively easy to prevent. If the surface temperature of the metal artifacts warms at a rate that is similar to the warming of the air, the dew point will not be reached on the metal surface, and condensation will not form. To facilitate the warming of the metal objects, a thin layer of insulating cold air that forms immediately adjacent to the metal surface must be dispersed. This is quite easy to do by simply using fans to move the air around the space. Fans should be turned on as soon as the outside air temperature goes above freezing and left on until the equipment warms to air temperature and does not cool down significantly again at night. This is usually a two to three week period when the fans should be operated. Simple box fans can be positioned around the space. Three or four per floor should be sufficient. Permanent ceiling mounted paddle fans also move air well and are inexpensive to purchase and simple to install. If mini-splits are used, they can simply be activated in a “fan” mode and allowed to run until the danger of warm, moist air enveloping cold metal machinery is past.

3. Temperature and Humidity Data Analysis

The American Precision Museum is commended for its long term monitoring of temperature and humidity using Hobo data loggers. Two of the Hobo data loggers were checked against a calibrated Vaisala hand-held meter and found to be relatively accurate.

	<u>Vaisala Meter Reading</u>		<u>Hobo Reading</u>	
Armory 1 st Floor	31°F	82% RH	31°F	78% RH
Armory 2 nd Floor	31°F	75% RH	31°F	78% RH

It is advised that the Hobo data loggers be sent in for recalibration at least every 2 years. As new data loggers are required, purchase Preservation Environmental Monitors (PEM's) instead of Hobos. The museum recently uploaded the data collected over the past 6 years to the PEMdata.org website designed by the Image Permanence Institute and continues to upload current data to this site. Please open the PEMdata.org web site to follow this data analysis (User ID and password are available from the APM Executive Director or Collections Manager). Preset the Date Range at "All." To zoom in on 2010, simply click twice on the right side of the graph. Select the "100%" icon below the again view all 6 years of data.

(A) **Armory Basement**, Select T (Temperature), then D (Dew Point). Note how close the temperature is to the dew point. Water will condense on any surfaces that drop below the dew point so when the two are very close there is undoubtedly condensation occurring, more likely in the summer when warm moist air infiltrates the basement and contacts the cold surfaces. Select RH (Relative Humidity) and note how high the humidity is year-round for this very reason. RH averages around 90% and seldom drops below 80%. Select Mold and observe when the risk is highest in the summer when the cold stone walls and floor will be very damp or wet due to condensation. The Mold function can roughly predict the extent to which metal artifacts will form rust because high humidity causes both. It is evident from the data that the basement is not safe for exhibition or storage of any collection artifacts as you have proven over the years.

(B) **Armory Upper Floors**— The Armory 1st floor where your best collections are located shows safer conditions, mainly because the brick walls are above ground and are warmed by the sun so condensation does not form on the interior walls. Also, it is somewhat isolated from the moisture that rises from the basement floor. Select T and then D and note now there is more of a separation of these two temperatures than in the basement with the dew point nearly always being 10 degrees lower than the space temperature. Select RH for both the 1st floor and the basement and you will note that it is consistently 20% lower than in the basement. Add the 2nd and third floor and note how the RH decreases on the upper floors. Although there is some moisture rising from the basement to the first floor that diminishes on upper floors, the RH decreases as one goes up mainly because the upper floors are warmer, especially in the summer.

Because of the increase in temperature and decrease in humidity, the upper floors are somewhat safer for collections. This can be determined by first observing the RH of each floor, and then the Mold function that helps evaluate the relative RH levels of each floor. By selecting RH and checking all three floors, it is obvious that the average RH is relatively high for exhibition and storage of collections on all three floors and that the preservation of all your artifacts could be enhanced by reducing the RH by at least 10% in the summer and 15% in the winter. By selecting T, it is evident that both your artifacts and visitors would benefit from lower summer temperatures. Fortunately, both these extreme conditions can be tempered by properly controlled air conditioning.

(C) Annex 1st Floor – Select T and then RH. Although environmental conditions could certainly be improved in this unconditioned building, they are relatively safe for the storage of the paper artifacts. Select Mold and see when you could have expected two mold outbreaks, but fortunately the damp conditions did not last long and it is doubtful that much mold grew even during these periods. Observe the basement conditions to understand why the basement should not be used for storage.

(D) Windsor Technology Park Storage – This is the best environment of all three buildings for preservation of artifacts, especially the large metal machinery that you store there. The T and RH functions show that it is minimally heated to 50°F in the winter and the temperature does not exceed 80°F in the summer. RH seldom exceeds 70% in the summer and is relatively dry in the winter, probably bottoming out at 20%. (Your Hobo data loggers do not register below 25% RH). Although this would be too dry for organic materials, it is fine for metals.

(E) Armory Lobby and Library – Select T and then RH for both areas. It is apparent that temperature is controlled for comfort throughout the year with the second floor library/offices warmer in both the winter because that is where the staff work, and in the summer because it is the second floor. Apparently the library data logger is not in one of the air conditioned offices. Also, the air conditioner in the north window is small for the library space as it does not cool much on the very hot days but does dehumidifies quite well in the summer because it is undersized for the space and running an lot.

(F) Armory Library Closet – Select T and then RH. The library closet appears to be part of the controlled space, maintaining 65 – 75°F year round. Although humidity can drop to a dry 25% in the winter, it seldom exceeds 60% in the summer making this one of the best storage areas for paper that you have.

(G) Armory Library Cabinet – Select T and then RH. This cabinet is apparently in the unheated space near the library as it gets quite cold in the winter. RH is relatively consistent but high for paper. Select Mold and observe how this space bumped up against conditions for mold growth from 2005-2008 although conditions appear to have been safer over the past two years.

4. Recommended Environmental Improvement Actions

(A) Armory Basement

The first recommended action is to prevent moisture from either entering the basement or from migrating from the basement upward through the rest of the building. In most historic houses, actions are taken to dry out of the basement so that the basement can become part of the interior building envelope. This would mean improving drainage around the building to keep water out of the basement, placing a heavy plastic sheet over the dirt floor or pouring a concrete floor that includes a vapor barrier to prevent moisture from entering through the floor, and insulating the walls, or at least applying a vapor barrier, and heating the basement or installing dehumidifiers to reduce humidity. Such actions would be very difficult to implement in the Armory basement because of the permanent water in the wheel pit and the porous nature of the laid stone foundation walls.

I believe a better solution would be to isolate the basement from the rest of the building by applying polyurethane foam insulation to the ceiling of the basement that is the bottom of the first floor exhibition hall's wood floor. As this floor has already been replaced and is no longer original material, there should not be a concern about applying cure-in-place closed cell high-density foam to the bottom of the floor and perhaps the sill area where the wood meets the stone. Since this type of insulation provides a good vapor barrier, it should stop moisture migrate to the upper floors, thereby reducing the moisture "pressure" on the rest of the building.

From experience with foam insulation at Shelburne Museum, I recommend getting several estimates for this large project as they can vary quite a bit. Also, go with a reputable installer and check references carefully, especially from owners who are living in spaces that have had foam insulation installed. If not mixed properly, there can be problems with curing and off-gassing. Have the contractor foam a small area of the ceiling and evaluate for several weeks for off-gassing before foaming the entire ceiling. Because the unprotected foam is flammable, it will have to be coated with intumescent paint to meet fire codes. The paint will cost nearly as much as the foam insulation. An alternative insulating method would be to install rigid closed-cell foam insulation between the floor joists but it would have to be cut to fit tightly and all joints with the wood joists would need to be well sealed with caulk or foam to provide an effective vapor barrier. The advantage to the rigid foam is that there would be no risk of off-gassing and it would be easily reversible.

I propose that the real value to the basement may be as an interpretive space for visitors. I find the wheel pit fascinating just as it is with water in the bottom and the laid stone walls are beautiful. Build plank walkways, print the interpretive drawings and text on Dibond that is impervious to moisture, and light the basement "walk" dramatically and safely.

http://www.graphicdisplayusa.com/prod_dibond

An audio tour could be written explaining how the water power system of the mill worked, why the wood waterwheel was eventually replaced with a water turbine, then

later fossil fueled steam power. If the foam on the ceiling was painted black and LED flood lights were mounted below the ceiling, no one would see the foam insulation.

(B) Armory 1st Floor Exhibit – Mini-split Cooling and Heating

The average yearly relative humidity for this space appears to be around 68% with RH levels reaching 80% during December and January. The environmental control goal for this large exhibition space is to reduce the RH throughout the year. Cooling during the hot summer months would also be desirable for visitor comfort. Both these goals could be accomplished by installing Mr. Slim or Citymulti mini-split air conditioning/heat pump units by Mitsubishi or a similar model.

<http://www.citymulti.com/>

The difference between the two is that only one to three Mr. Slim units can be run from an external condenser, whereas the Citymulti connects several indoor air handlers to run off the same group of external condensers. These small fan units with integral heating and cooling coils mount directly on the wall and do not require any ducting. Insulated pipes connect the compact air handlers to the small outside heat pump/condenser units.

Mini-split systems are ideal for cooling and heating large open spaces such as the Armory. Direct exchange cooling units (such as window air conditioners and mini-split units) can effectively reduce high temperatures and relative humidity as long as the units are running. Conventional air conditioners can cool the space too quickly and then shut off at which point dehumidification ceases until the room heats up enough to turn on the AC, repeating the cycle. To effectively use direct exchange cooling technology for dehumidification, the units must be undersized for the space so that they run continuously at a low level during hot humid weather.

The Mitsubishi mini-split units use inverter technology to automatically adjust the cooling capacity of the units for the conditions of the individual spaces, running the AC at a low level when only minimal cooling is required and at higher levels when more cooling is necessary, thereby maximizing both cooling and dehumidification. They also have a “dry” control setting that cycles the AC on for 3 minutes and off for 3 minutes so that the unit runs longer periods of time at a very low level without over-cooling the space.

They will be less effective at heating in the winter because it is not practical to insulate this large inefficient structure to retain heat. However, the heat does not need to be increased much to reduce the high humidity during the winter. By heating the exhibit space from 25°F to 35°F, the RH would be reduced from 82% to 68%. Also, but reducing the RH by at least 10% year round there will be less moisture retained by the wood floors and that could result in another 5-10% reduction of the maximum RH levels. Isolating the damp basement could decrease RH upstairs by another 5%. All these RH reductions are improvements in the right direction for the long-term preservation of your artifacts.

Mini-split Advantages

- (1) They can be easily mounted on the walls and connected to outdoor condensing units with minimal disruption to the historic building structure. There are also floor standing units available that may be desirable for this exhibit space.
- (2) They do not require expensive and obtrusive ducting to distribute the conditioned air.
- (3) They cost about 40% of the cost of traditional ducted HVAC systems.
- (4) They are more efficient than conventional HVAC systems and therefore less expensive to operate. Although it is difficult to quantify, from experience I would estimate that operating costs are about 50% of the operating costs of a traditional ducted HVAC system if the building is not being heated to comfort levels in the winter.
- (5) They are very quiet.
- (6) They can be installed in stages so that proper sizing of the system to meet the heating, cooling, and dehumidification requirements of the space is facilitated.

Mini-split Disadvantages

- (1) Mini-split systems cannot dehumidify as well as traditional museum HVAC systems that super-cool then reheat the air. They generally cannot dehumidify down to 50% RH on humid summer days. They can dehumidify down to 60% RH on humid summer days and this would be safer for your collections than your present conditions.
- (2) Mini-splits also do not heat as well as conventional HVAC systems especially in colder climates. This is because the heat is supplied by an air-to-air heat pump and the colder the outside air, the less heat can be extracted to heat the building. In fact, an alternate heat source is required in the winter in Vermont for human comfort. This is not a serious shortcoming for the Precision Museum since you do not plan to heat your building to comfort levels in the winter. The mini-splits will provide enough heat during cool shoulder seasons to reduce the humidity to 55%. Although it would be desirable to introduce some heat into the building even during the cold winter months to reduce the high humidity, this may not be economically feasible because the building cannot be insulated and any heat introduced may quickly dissipate through the cold brick walls.
- (3) Mini-splits are supplied with complex internal control systems and it is difficult to take external control of the units with another digital control system to effect humidistatically controlled heating or cooling. Therefore, they are more difficult to customize and fine tune for precision control than conventional HVAC systems. Fortunately, tightly controlled environmental conditions are not required for the long-term preservation of your industrial machinery and archives material. The primary

goal of practical environmental control is to reduce the temperature and humidity extremes that present the greatest risk for damage to collection artifacts at a cost that is sustainable, and mini-splits fit that requirement.

(4) As with all system solutions to environmental control, expertise is required to operate, maintain, and troubleshoot the equipment operating in a somewhat unconventional mode (humidistatically controlled heating). To effectively use any mechanical systems, it will be important to monitor collection spaces on a daily basis and reset set points or the operating mode of the mini-splits (from “heat” to “dry”) at least seasonally and sometimes monthly. Although control and equipment specialists will be available on a contract basis, on site interest and expertise is critical to maximize the performance of this equipment. I would estimate that an average of four hours a week will be required (10% of a full time position) to train on the system and operate it on a continuing basis.

Advice for Selection, Installation, Sizing, and Operation of Mini-splits (from experience)

(1) Mitsubishi mini-splits are recommended because Mitsubishi is the only manufacturer of mini-splits that manufactures and distributes all the parts for their units. They also have a very good service and technical support team in Vermont that works out of Homans Associates in Williston, VT. The Mitsubishi technical support representatives have been very helpful in providing timely advice and assistance for adapting Shelburne Museum’s Mr. Slim units to remote sensing and humidistatic heating.

(2) Purchase the “P Series” units, not the “M” series as they cannot be easily modified to reference remote sensor locations nor can them be modified for external control to effect humidistatic heating. Investigate the “Zubudan” model for maximum heating capability down to -25°C (-13°F).

(3) Purchase the optional wired remote control since they contain an external sensor and can be mounted at eye level in the comfort zone. The basic units are supplied with a wireless hand-held remote control which limits settings and operations, and an on-board temperature sensor that senses temperature at the unit that is usually mounted high on the wall. In a room with tall ceilings, the temperature at 9 feet can be markedly warmer than the temperature at 5 feet. It is important to operate the equipment to maintain desired conditions where the people and artifact exist.

(4) Investigate the various control options that allow control from a PC and over the internet. Centralized control becomes more important as you add more units.

(5) Your consulting engineers should determine the number of units recommended to cool the Armory first floor gallery for comfort, then reduce the number of units to ensure the system is undersized and the AC runs continually to maximize dehumidification on hot, humid days. This may result in cooling only to 80°F on summer design days, but when it is 95°F outside visitors will be comfortable at 80°F

inside especially if the humidity is lower. I recommend installing fewer units than required for 72°F comfort and running the system for a full year through all 4 seasons while carefully monitoring temperature and humidity levels. After the first year, units could be added if necessary. By staging implementation in this manner you can ensure that you maximize the use of the equipment to maintain a safe environment for your collections at the lowest cost.

Sizing mini-splits for humidistatic heating during cold weather is also much different than sizing for human comfort. It is seldom that the temperature has to be raised more than 10°F to effectively reduce humidity to safe levels. For example, if the temperature is 25°F and the RH is 75%, raising the temperature to only 35°F will reduce the RH to a much safer 61%. Therefore, the mini-splits should be sized and operated to raise the space temperature only 10-15°F rather than to a comfort level of 68°F. It may be necessary to add more units for humidistatic heating in the winter but not operate all of them in the summer cooling mode.

(6) Investigate methods of controlling the units in the spring, fall, and winter heating mode using humidistats instead of thermostats. This is very important since humidistatic heating is the primary method to control humidity during cool damp weather. The newer mini-split controls may have this capability, but at Shelburne Museum we use an external digital control system to effect humidistatic heating. The Sequence of Operations for cooling and dehumidification in the summer and humidistatic heating in the winter is attached as **Appendix 2**.

(7) Use Vaisala humidity sensors for outdoor sensing and humidistatic heating. Temperature sensors purchased from any reputable manufacturer will be accurate across a wide temperature range. However, this is not the case with humidity controls. Most measure RH accurately when the temperature is in human comfort ranges of 60-80°F, but high-end controls such as Vaisala are required to accurately measure RH when the temperature is 0-50°F and this is the range in which humidistatic heating operates. Vaisala sensors are about half again as expensive as standard RH sensors. <http://www.vaisala.com/en/buildingautomation/products/humidityandtemperature/ductandwallmounthumiditytransmitters/Pages/HMDW6070.aspx>

The New England Vaisala office is located at 10-D Gill Street, Woburn, MA, 01801, (781) 933-4500. Their sales and technical support departments are very responsive and they run an efficient calibration service.

(8) Many digital control systems can be used to control the mini-splits for humidistatic heating. Select a control brand that your consulting engineers are most familiar with and that has the best reputation for service in your area. Make sure the company service technicians understand that for at least part of the year you are controlling the exhibit and storage spaces based on humidity, not temperature, to maintain safe conditions for the artifacts, not comfort for visitors or staff. Reputable manufacturers include Johnson Controls, Honeywell, Andover, Control-Pak. Be sure to select controls that are easy to operate and that your staff is well-trained on how to operate them.

(9) Allow time and funding for specific training on regular monitoring and trend reading as well as setting and operating the mini splits in the summer and winter mode during the first year of operation.

(C) Armory 2nd Floor Storage

Artifact Storage

At least two thirds of this floor is devoted to artifact storage. The artifacts are similar to those on exhibit downstairs, large and small metal machinery with associated parts and related interpretative items. In general, the artifacts are in good condition in spite of the high RH in the winter and heat in the summer. It is possible that this space could be retrofitted as an exhibit area in the future. Regardless if whether this 2nd floor is used for storage or exhibition, it would benefit from the same type of environmental improvements recommended for the first floor, mini-splits properly sized to maximize dehumidification in the summer and humidistatically controlled heating to decrease humidity as required in the other three seasons.

Archival Storage

About a third of this space is used for archival storage. As the archives require a lower RH level than is achievable with the mini-splits alone, it is recommended that a 1200+ square foot “room within a room” be constructed on the east end of the second floor for easy access from the library/office space. (NOTE: this space could also be built on the 3rd floor if it is decided that is a better location). Build the room larger than needed to allow for expansion of the archives. This room could be constructed using either conventional wood framing with densely packed cellulose insulating the walls, floor, and ceiling, or pre-constructed foam panels. If conventional balloon construction and densely packed cellulose insulation is used, do not use a vapor barrier on the interior side of the walls. The cellulose is designed to act as a humidity buffer, absorbing moisture in the summer and releasing it in the winter, and a vapor barrier would hinder this process. However, I suggest that a polyethylene sheet vapor barrier be installed on the exterior of the walls, floor, and ceiling to prevent the cellulose from absorbing moisture from the rest of the 2nd floor storage area. Confirm this recommendation with your engineers.

The humidity buffering effect of the cellulose will contribute significantly to maintaining a stable humidity in the space. However, so will the large mass of paper that you store in the room. Your engineers should be able to advise on whether the cellulose insulation will be a major factor to stabilizing RH as compared to the mass of the paper stored in the room. If it is not, then there would be no disadvantage to using rigid foam insulation panels to construct the room and that would be an easier building method, though probably more expensive. There was also a desire voiced to make the room easy to disassemble so that the entire 2nd floor of the Armory could house exhibition at a future time. A room constructed of rigid foam panels would probably be easier to disassemble and move to another floor or location if this is a serious consideration.

The exterior walls of this interior room should be at least three feet from the north and south exterior building walls so that a microclimate is not formed in the space

between the walls. The room could be built directly against the library wall but there should be insulation between the archives storage room and the brick wall of the library. A mini-split could be used to cool and dehumidify the space in the summer, but since it could only dehumidify to about 60% on hot humid days, a commercial dehumidifier should also be purchased to further reduce RH to 45-50%. The dehumidifier recommended is the Hi-E Dry. Although it costs over twice as much as a residential dehumidifier, it uses less energy and over 10 years will pay for its higher cost in energy savings.

http://www.sylvane.com/hiedry-100-dehumidifier.html?s_kwcid=cse_gps

Although the dehumidifier will add some heat to the room, I anticipate that the cost of running both the dehumidifier and the mini-split AC unit on hot summer days will still be less than operating a conventional HVAC system that would super-cool and reheat the air to dehumidify the room and the purchase and installation of the mini-split and dehumidifier will also be less. However, you should have your engineers price this option against a small conventional HVAC system that super-cools and reheats the air to dehumidify, especially since you already have a boiler that could supply hot water for the reheat coils for the archives. However, that option would require running water above your 1st floor exhibit area.

Using the mini-split in the humidistatic heating mode should maintain humidity at about 45% in the winter inside this well insulated room, as long as there are no plans to heat the archival storage space for human comfort. Withholding heat from the archives storage area will also better preserve the paper artifacts as the cold temperatures will significantly reduce the chemical reactions that cause paper to deteriorate. If human comfort in the storage area during the winter is a priority, then a humidifier would have to be installed and set to maintain 40%RH. This would also require water in the room above the exhibits.

(D) Armory 3rd Floor Storage

The same environmental control strategies and equipment that is used to condition the first floor exhibit and second floor storage area could be used for the third floor storage area. More mini-split units may be required for the third floor since the summer heat loads increase as one moves up through the building.

(E) Very Low Impact Approach

There is a very low cost and low impact approach to environmental control that should also be considered. With the exception of the paper archives, given the observed condition of the artifacts and the many years they have been stored or exhibited in the uncontrolled Armory, I suggest that it would NOT be irresponsible to leave conditions as they are now. The damp basement should be sealed off from the upper floors to prevent moisture migration upward, and a sealed, conditioned room is required to improve environmental conditions for the archives. However, the large metal industrial machinery that forms the core of the collection is in quite good condition even though it has been stored and exhibited in what would be characterized by most museum standards as adverse conditions. The preventive conservation action of using a wax/oil coating to protect the metal surfaces that you presently employ appears to be controlling rust that is the major concern for your core

collection. If rust does occasionally form, it can be removed with some effort, but perhaps less effort than will be required to maintain even the mini-split environmental control equipment. Installing no mechanical equipment would certainly require less energy use and be less expensive. At this point, I would still recommend pursuing grant opportunities to support gradual installation of mini-split systems as detailed above followed by at least a 1-year evaluation of performance before installing similar equipment on the second and third floor. If on evaluation it is determined that 1st floor conditions were not significantly improved as compared with the cost in time and resources required to operate the systems, I would not recommend installing similar systems on the second or third floor. It is fortunate that grants are available to fund this type of improvement and evaluation.

5. Fire Detection and Suppression

I recommend upgrading fire detection by installing an Aspirating Smoke Detection (ASD) system. The ASD I am most familiar with is VESDA, an acronym for Very Early Smoke Detection Apparatus. An ASD unit actively “sniffs” the air and detects the very early incipient stages of fire, usually sounding or sending an alarm before flames are noted. It can even detect if a person is smoking in a building. It can indicate where the potential problem (such as wires heating up and melting the plastic coating) is located so that it can be addressed before it causes major damage. For more information on VESDA, go to: <http://xtralis.com/p.cfm?s=22&p=244>

Although fire suppression may be well beyond the scope of your project, an ideal fire suppression system for museums is the water mist system. If it does activate, very little water is used to extinguish the fire minimizing the potential water damage to the collections. Although more expensive than conventional wet or dry pipe systems, this new system is being used in more and more museums and historic houses. For more information on the mist system, see the following manufacturer’s web sites.
http://www.hi-fog.com/index_EN.shtml
http://www.hi-fog.com/en/land-applications/lhoh/museums_EN.shtml

Nick Artim is an expert who consults exclusively on fire protection for historic buildings. Nick also designs ASD fire detection systems and conventional wet and dry pipe sprinkler systems. He has pioneered the use of water mist suppression systems in historic house museums in the US.

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6. Conclusion

The American Precision Museum is well positioned to implement practical environmental improvements. Competent professionals have surveyed the building and collections. Building structural problems are being addressed. The artifacts have been proofed to extreme conditions over many years. Temperature and humidity levels in the Armory Building have been monitored for more than a year, indicating where environmental problems are most serious. The next logical step is to improve the interior environments. The staff is knowledgeable and diligent in properly implementing preventive conservation actions. This is very important because the implementation and maintenance of practical climate control methods requires staff who understand the concepts and implications of these methods.

Implementation of the recommendations in this report will improve conditions and result in savings in energy and money as compared to conventional HVAC systems. However, there is no “free lunch.” Compromises will have to be made to realize such savings. The building will be cold in the winter affecting comfort and programming. Local experts will have to be located who understand the somewhat unconventional sequence of operations for the equipment and are proficient at troubleshooting, repairing, and maintaining the systems. Careful environmental monitoring is crucial to insure the systems are working properly. All things considered, I believe that the American Precision Museum is a good candidate for the practical climate control methods and systems proposed.

Finally, monitoring and quantifying temperature, RH, and energy costs before and after improvements to the Armory building would be important research that could lead to articles that would be welcomed by the museum community. For example, it would be a service to the field to determine the cost per square foot to cool and dehumidify the large, brick Armory building. There is a lot of interest in implementing such practical climate solutions in historic buildings but the results of such environmental actions have not yet been quantified or published. Efficiency Vermont could advise on how to measure energy usage and may offer incentives to use some of these lower-cost strategies such as insulating the basement ceiling and the use of mini-splits. With your knowledge and interest in such environmental improvements and talented local consultants working on your team, the American Precision Museum is well positioned to conduct this practical research and publish the results. I would be glad to advise on how to structure such research and review articles for publication.

Please do not hesitate to contact me if I can be of additional assistance in implementing these recommendations.

APPENDIX 1

SUMMARY OF RECOMMENDATIONS

1. The goal of this environmental improvement project for the Armory exhibition and storage areas is to reduce maximum humidity levels in the summer from 70% to below 60% and in the winter from 83% to below 65%. Summer maximum temperatures will be reduced from 83°F to 75°F and winter minimum temperatures will be increased from 25°F to 35°F to reduce the high humidity. Changes between winter and summer conditions will be gradual, following outdoor seasonal changes.
2. The goal for the archives storage area will be 50% RH and 72°F in the summer and 40%RH at cold temperatures in the winter with gradual seasonal changes. The library and staff offices will be heated and cooled for human comfort.
3. Continue to monitored temperature and humidity levels using existing Hobo data loggers and store and interpret data on a regular basis using the PEMdata website. Hobo data loggers should be returned to the manufacturer for recalibration at least once every two years. As new data loggers are required, purchase Preservation Environmental Monitors.
4. Use fans to move the interior air in early spring to facilitate warming of the metal machinery and prevent condensation from forming on metal surfaces.
5. Do not use the basement for storage of collection artifacts. Maximize the use of the Windsor Technology Park storage area as it has the best storage conditions of any of your spaces.
6. Isolate the Armory basement from the rest of the building to prevent moisture from moving up through the building by installing insulation and a vapor barrier beneath the first floor.
7. Install minisplit cooling and heating units in the Armory 1st floor exhibition space. Install or operate fewer minisplit units than required for visitor comfort so that they run longer at a low level to maximize dehumidification. Run the minisplits for a full year and monitor conditions. Add more units if required to reduce temperature and humidity extremes.
8. Install humidistatic controls to operate the minisplits so they will heat to dehumidify the exhibitions during cool, damp weather and withhold heat allowing the building to cool when the humidity is below the set point.
9. Install minisplits in the 2nd and 3rd floor storage areas basing the number of units on lessons learned from the 1st floor exhibition area.
10. Construct a well-insulated “room within a room” on the 2nd floor to house the archives. Control temperature and RH to 68°F and 50% RH in the summer and maintain as low a temperature required to maintain 40-45%RH in the winter. Use a minisplit unit to cool archives storage in the summer and provide humidistatically controlled heating during the rest of the year. Use a Hi-E Dry dehumidifier to reduce RH in the summer.

APPENDIX 1

11. A very low impact approach that would save energy and money would be NOT to install any equipment or systems to improve environmental conditions on the 1st, 2nd, or 3rd floors of the Armory. In my opinion, this would be an unconventional approach, but not an irresponsible one given the observed condition of your core collection of metal machinery.

12. Consider installing an Aspirating Smoke detector (ASD) throughout the Armory as a significant upgrade to fire detection capabilities.

13. Track environmental conditions and quantify energy usage before and after environmental improvements are made. Quantify initial cost per square foot of mechanical systems and continuing costs of operation of the systems. Do this for the first floor and use this data to guide decisions on installing systems on the 2nd or 3rd floor of the Armory. Obtain estimates from engineers of initial purchase and operating costs of a traditional museum HVAC system designed to maintain 50%RH + or – 5% and 68°F + or – 3°F. Publish the results comparing the conditions maintained and the cost.

APPENDIX 2

Sequence of Operation for Mini-Split AC and Heat Pumps

1/15/2011

MINI-SPLIT CONTROLS

Operator must set mode at Mini-Split to “Dry” when the outdoor temperature is consistently above the Mode Set Point (65°F adjustable) and “Heat” when the outdoor temperature is consistently below the Mode Set Point.

When set to “Dry” mode, the mini-split will cool for three minutes, then turn off for three minutes so that the coils do not freeze, then cool for three minutes, etc. In the “Dry” mode the mini-split will cool as low as 67 degrees.

When set to “Heat” mode, METASYS powers on the mini-split if the zone RH is above the RH Set Point (55% adjustable) and the temperature is below the Maximum Temperature Set Point, or temperature drops below the Minimum Temperature Setpoint.

Each mini-split is controlled by its own Vaisala temperature/RH sensor.

JOHNSON CONTROLS METASYS

Cooling and Dehumidification Mode

When outdoor temperature exceeds Mode Set Point (65°F adjustable), Metasys powers on the mini-split, allowing cooling and dehumidification to be controlled entirely by the mini-split setting (Dry, Cool, or Auto).

Humidistatic Heating Mode

When outdoor temperature is below the Mode Set Point (65°F adjustable) and the zone RH exceeds the RH Set Point (55% adjustable), Metasys powers on the mini-split that is set to the “Heat” mode to warm the space as high as the Maximum Temperature Set Point. As soon as the RH drops to set point, Metasys will turn the mini-split off. If the zone humidity is below the humidity setpoint, the Min Temp Setpoint will be used to activate the mini-split in “Heat” mode to maintain the space at setpoint.

Set Points: (3-6 adjustable)

1. Outside Air Temperature (Read Only)
2. Outside Air Humidity (Read Only)
3. Zone RH 55%
4. Maximum Zone Temp 75°F
5. Minimum Zone Temp 15°F
6. Mode Set Point 70°F



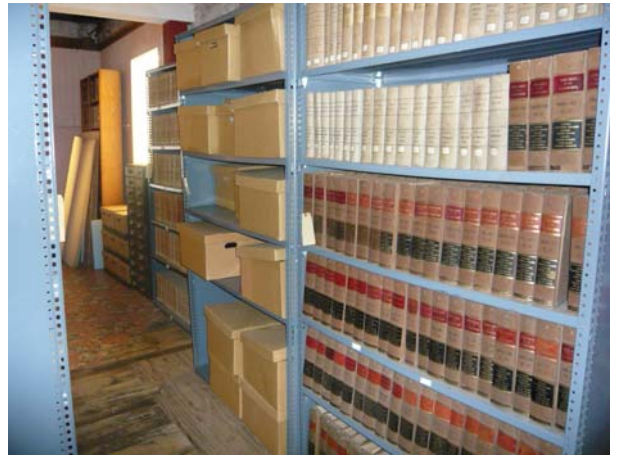
1st Floor Exhibit A



1st Floor Exhibit B



2nd Floor Archives A



2nd Floor Archives B



2nd Floor Archives C



2nd Floor Storage A



Left:
2nd Floor Storage B



Right:
2nd Floor Storage C



2nd Floor Storage D



3rd Floor Storage A



3rd Floor Storage B



3rd Floor Storage C



Attic Storage A



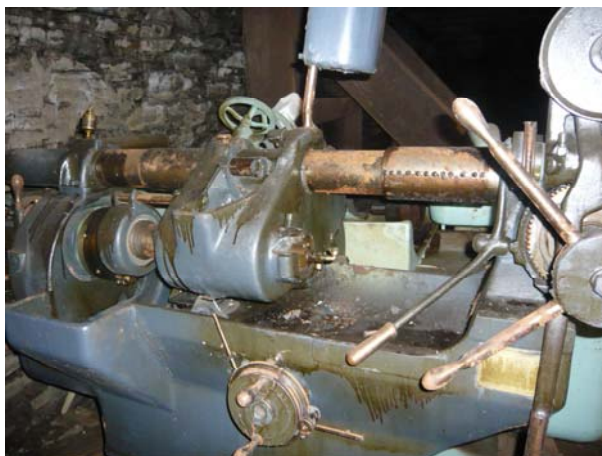
Basement Storage A



Basement Storage B



Basement Storage C



Basement Storage D



Basement Wheel Pit



Basement Detail



Annex 1st Floor Storage



Lobby



Library Offices



Attic Storage A

Right:
Attic—Stairs to
cupola





Rust on Machine



Rust on Machine Detail



Flaking Paint, A, B and C



Tech Park Storage A



Tech Park Storage B

KEEFE & WESNER ARCHITECTS, P.C.

ARCHITECTURE & PLANNING

CONSERVING THE COLLECTION: American Precision Museum Inter-Disciplinary Planning Study and Preventative Strategies

Funded by an NEH-SCHC GRANT for Sustaining Cultural Heritage Collections February 25, 2010

Participants: Ann Lawless, Executive Director APM; Blaine Cliver, Board Member APM; Beau Harris, Collections Manager APM; John Alexander, Collections Technician APM; Nancy Hoggson, Development & Communications APM; Richard Kerschner, Conservation Consultant on Museum Environments; Robert Neeld, P.E., Engineering Ventures, Inc., Civil and Structural Engineering; Daniel Dupras, P.E., Engineering Services of VT., Mechanical Engineering; Thomas Keefe, Keefe & Wesner, Architects, PC, Preservation Architect.

Foreword

In 2010 the American Precision Museum, Ann Lawless, Executive Director, successfully applied for an NEH-SCHC Planning Grant targeted at inter-disciplinary strategic planning of preventative measures to ensure the long-term protection of the 1846 Robbins & Lawrence Armory and the significant cultural collections it houses. Ann Lawless assembled a team including a museum collections conservation expert, a preservation architect, a civil engineer and a mechanical engineer, to work with Museum Staff, Board and Executive Director reviewing existing conditions, discussing Museum needs and plans for the short and long-term and making recommendations to improve collections storage, handling and conservation – including the largest single artifact, the Armory building itself.

The Study procedures, developed cooperatively by all involved, included dissemination of background documents (Existing Condition drawings; HAER drawings; history of building and institution; collections and environmental monitoring data; etc.), a preliminary familiarization site visit for engineers and conservation specialist, and on-site meetings and discussion with staff, Board and Executive Director to review conditions, current practices and policies and discuss options for addressing them. Draft reports were developed, exchanged and reviewed by all parties, and additional research and discussion, including a telephone conference of principal consultants, led to the recommendations in this report.

Existing Conditions

The American Precision Museum owns and curates a world-class collection of machine tools and related artifacts housed in the historic 1846 Robbins & Lawrence Armory, itself the collection's largest and single most-important artifact. Key staff consists of an Executive Director, a Collections Manager, a Collections Technician/building manager, and a part-time development/communications specialist. The un-heated 40 x 100 foot 3 ½ -story Armory and 40 x 40 foot 2-story east wing, which is partially insulated and heated, are open to the public from late May to October, with exhibition space occupying the ground floor of both sections and museum offices on the 2nd floor of the wing. Additional storage of artifacts and related materials occupies all of the remaining floors of the armory. The dirt-floored Armory basement contains the 20 x 40 foot water wheel pit. The east wing partial basement is heated and has a concrete floor; it contains a mechanical room for the gas-fired hot water furnace and some additional

storage/workshop space, and has direct access to the exterior terrace on the NE, and to the Armory basement.

The roughly rectangular site slopes to the east and north, and includes a gravel drive from State Highway 5 on the NE passing around the east wing and along the entire south side of the Armory, and exiting to Maple St., a small paved road on the west by crossing via a deeded R.O.W. property owned by Central Vermont Public Service on the west. CVPS also retains ownership of a narrow strip of steeply-sloping land to the south of the gravel drive, which includes a cast concrete base for an electrical sub-station now removed. The property is bounded by a newer fenced substation on the west, and by Mill Brook on the north, which flows east to the Connecticut River approximately 1/2 mile to the East. Steep banks on the east and south, and sloping ground on the west direct surface water towards the building on 3 sides, and the site falls away steeply to the brook on the north, exposing all of the basement level and some of the stone foundation.

Site and Building Issues

The Armory has recently had a new slate roof installed (2005), structural reinforcement of the 1st floor (1980; 2006), upper floors, roof and cupola (2005-6) and restoration of 110 of the 165 large 12/12 window sash (2004-5), as well as smaller interior renovations to provide new wiring, some utility work and storage space and improve Code compliance. The east wing has a mechanically-fastened membrane roof installed c.1990. A thorough survey and study of the exterior masonry walls was done in 2008, and a first phase of masonry stabilization carried out in 2009. A HAER Study and documentation of the water-powered system involving the wheel pit and former millrace, including drawings and history tracing the evolution of the building and its uses, was completed in 2009. Around 1980 the building had extensive work done on drainage to alleviate trapped water and related problems on the south side by providing collection and channeling of stormwater under the building to the brook; a minor amount of additional surface drainage was installed on the west in 2010. A paved terrace on the NE constructed in 1991 that contributed to splash and drainage problems with the masonry walls is about to be removed and re-landscaped to address both functional and aesthetic needs; a concurrent review of the c.1935 concrete retaining wall supporting the south bank of the brook as it approaches the Rt.5 highway bridge just southeast of the museum has just revealed deterioration and weakness that is being addressed in conjunction with the landscape renovations. Engineer Bob Neeld has suggested that regular monitoring commence now; repairs will be needed sometime in the next 5-20 years, and he has estimated the probable cost in the range of \$50,000-60,000. He has also reviewed previous drainage work on the south and west, and recommended identifying the in-place drainage, improving surface drainage on the west with a better swale pitched towards the brook, and additional membrane gutter drainage around the south and possibly east sides of the east wing, in addition to the membrane gutter planned for the north side.

The Armory, an unheated historic load-bearing masonry building, has no insulation or storm windows, and no heating or mechanical systems at all, other than a small pair of bathrooms on the main floor adjacent to the east wing with plumbing to the heated east wing basement. Conservation concerns include the fluctuation of temperature and humidity, and attendant condensation issues, which are particularly important because much of the collection consists of iron machine tools – which are vulnerable to condensation and thermal stresses, and too heavy and bulky to be easily moved. Lack of tempered or heated spaces in the Armory makes storage

and handling of paper, wood, cloth, photographs, maps, drawings, etc. in this section challenging in warm weather and impossible in winter months and much of the swing seasons. Roof leaks, formerly a major problem, appear to have been solved, but walls and 1/3 of the windows still need additional restoration to tighten them up. The long north and south walls of the Armory both bow at the center towards the river; this is a long-term, slowly-developing condition not unusual in 19th C un-reinforced masonry walls and monitoring is being set up to develop additional information and determine whether movement continues. Repairs in 1980 may have addressed this with installation of ‘deadmen’ on the south anchored to the walls, but documentation of this work is incomplete, and the extent of stabilization measures has yet to be fully determined.

Museum Staff has gathered and continues to gather information about all installed, altered or abandoned drainage work in the last 30 years; together with the detailed information from the HAER Study on sub-surface historic water control structures, it will provide a good baseline for any consideration and recommendations for additional drainage and grading around the building. Dye tests in January 2011 have indicated that the drainage from the south side do pass under the building to the stream; a second drain from the mechanical room in the NE corner of the east wing basement leads under the NE terrace towards the brook, but the exact location of the outlet was not detected. It will be further investigated, and improved if necessary, during summer 2011 construction of the terrace renovations. It appears likely that additional drainage work will be needed including a sub-surface membrane gutter on the south side of the east wing (where water enters the basement in wet weather), and along the north side of the east wing where a new membrane underground gutter is planned as part of the Spring 2011 Landscape work (Shep Butler, Landscape Architect is directing that project). Some additional grading may also be possible on the west without disturbing the archaeological discoveries there.

Planned improvements include preservation-quality storm windows for heated portions of the building along with appropriate preservation-conscious air sealing and repairs to the historic masonry and woodwork, including window and door frames. The existing gas-fired hot water heating system installed in 2009 appears adequate for the human-occupied environments in the building with minor changes and up-grades; friends of the Museum with expertise in heating systems have offered to provide pro bono expert advice and design to enhance this new system, and Mechanical Engineer Dan Dupras has reviewed it for this study and recommends keeping it in service with some relatively minor improved details.

Lack of separation between the basement and upper floors and the presence of substantial quantities of water in the basement from springs in the wheel pit and from seepage through porous masonry foundations on the three sides where exterior contours allow water to flow toward the building results in uncontrolled humidity fluctuations within the building. Architect, engineers and consultant have all reviewed this condition and we do not feel that there is a practical or even remotely economical way of excluding water from the basement, especially as there are important archaeological remains of the original sluiceway just outside the west wall, which were initially designed to channel water *into* the basement, and sloping ledge that surfaces inside the west basement provides an excellent pathway for drainage from the west to enter the basement. Fortunately the wheel pit and former tailrace offer a pathway to get water from all of these sources back out to the brook. Control and channeling of groundwater around and through the foundation needs to be improved to prevent damage to the historic masonry foundations;

improvements will include minor re-grading at south and west sides near the foundation to enhance surface run-off away from the foundation, and cleaning/maintenance of existing intakes, channels and drainage from the south yard and basement – and particularly the wheel-pit – to the brook.

Separation from the rest of the building can be achieved at the underside of the 1st floor by using an environmentally-friendly soy-based two-component spray-applied semi-rigid polyurethane foam with a release barrier protecting the stone masonry foundation; it can be applied between the 1980 Doug fir beams and joists against the floor planking, since all these are new, non-historic materials, and the foam will constitute both an air and vapor barrier. This will need to be treated with an intumescent paint to meet Fire Code requirements, and can be painted black to ‘disappear’ above new lighting that could be installed should the museum decide to interpret the wheel pit and basement. Stored machine tools here have just been removed to a more appropriate storage location, and structural repairs to the 1980 work were carried out under direction of then-Board Member Robert Pantel. Additional work will involve safe walkways and railings, signage and interpretive graphics, lighting, ventilation or any tempering of the basement and Code-mandated exits signs, emergency lights, etc. to enable the public to see this important piece of the building’s historic structure. Tall wood columns at the wheel-pit will either be shortened if it is filled in, or will need bracing against lateral forces. Push-pull fans, one at each end of the basement, are recommended to help control potential humidity and provide sufficient ventilation air.

The partial basement of the east wing has a concrete floor in the developed section, and enough heat to keep it frost-free in winter, allowing storage of paint and other materials. Old fresh-air vents at the mechanical room that have been superseded by a newer and smaller vent should be removed, and the wall patched with appropriate and compatible materials; the rated enclosure for the mechanical room appears to be sufficient for fire safety. Efflorescence on the interior face of brick foundations here suggests moisture migration, probably exacerbated by heating in winter, that will need to be addressed, and may require excavation on the exterior to examine and devise protection for the porous historic masonry foundation. Wood grounds and lintels/door frames in the masonry on the north are important historic remnants that should be preserved, and will need restoration and repair; new grades established by the current Landscape Project will respect historic openings and avoid creating negative drainage.

Fire-safety, code-compliance and functional requirements for circulation, access and use of the various parts of the building are also an on-going consideration; Museum staff and consultants have engaged constructively with Code and safety officials on the State and local levels to address improvements and move the building towards better safety and access features. A 2003 walk-through with State Fire Marshals provided a checklist that includes improved smoke/fire detection and notification, fire separation between the historic 4-story stairway shaft and the Armory, improved exit pathways, consideration of new stairs and an elevator near the west end and miscellaneous small upgrades and repairs to mechanical and electrical equipment.

We contacted the Fire Marshall to review briefly the proposed improvements from this study, particularly the room-within-a-room storage space planned for the 3rd floor; other than extending the fire alarm and notification system to this space, and maintaining the two current exits off the 3rd floor, there are no special requirements. Improvements to fire safety features are being

addressed incrementally with each phase of work; a new and complete fire and smoke detection and alarm system is likely to be the next work from this list to be undertaken. Egress, fire ratings of materials and detection/suppression mechanisms will be a necessary part of planning for the new internal storage space and for any other work on the building.

The building is currently not accessible except at the 1st floor (and not fully accessible there), has limited fire/smoke detection and no sprinkler system, and only a vintage rope lift that does not meet current safety standards for human use – it is used sparingly, unoccupied, to move moderately heavy/bulky items between floors. Several chain hoists with I-beam channels and floor hatches and/or large exterior loading doors make movement of heavier machinery possible. Hired riggers are needed to move the largest and heaviest items; some of these are stored off-site in rented space. Accessibility improvements will be required as part of the proposed work¹ and may bring consideration of the new elevator into play; its location should be considered in planning for these and any other changes to the building.

In addition to being a strong recommendation of the State Fire Marshall, a good fire detection and alarm system is an important and necessary component of collections preservation. An Aspirating Smoke Detection system (ASP) is the system best suited to protection of valuable collections of cultural artifacts and buildings that house them; it is in use at all scales from national landmarks to local institutions, and provides some of the earliest and most accurate warning of incipient combustion. The basic system typically involves ¾" main (CPVC plastic) tubes with 1/4" branch 'sniffer' tubes installed unobtrusively in mostly concealed locations throughout the building, that sample the air in each space by bringing a small amount to a central detector for analysis. The air sampling unit controls and filters the air movement across the detector which allows it to be set to a more sensitive level than conventional ionizing smoke detectors. Subsequently it can detect a fire earlier in the smoldering process. While the analyzer needs to be in a heated space, and samples must be warmed above freezing for analysis, the detection works well when monitoring areas that are not heated in winter. Most of the installation involves placing the tubes; openings at the spaces can be very unobtrusive, and the electrical components are limited to the pump(s) and central detector/analyzer, hooked into the Fire Alarm Control Panel that also monitors other detectors (e.g. rate-of-rise heat detectors in mechanical room or attic, etc.), controls the sprinkler system when there is one, and signals the monitoring service when trouble is detected. An ASP system for the APM would be likely to cost in the range of \$20,000-25,000. Additional costs would be required for the Fire Alarm Panel, other types of sensors, and for the monitoring service.²

Structural support for loading associated with both concentrated paper files and heavy industrial machinery appear to have been addressed in previous repairs and any new or relocated storage spaces will need to review structural requirements for this type of loading.

¹ Vermont requires that up to 20% of a project's cost be allocated to making the building accessible.

² Nick Artim, Director, Heritage Protection Group, P.O. Box 895, Middlebury, VT 05753 (802) 388-1064, firesafe@gmavt.net ; provided cost estimate; he designs and oversees installations.

The Museum also owns a c.1970 2,000 s.f. storage building called the Annex, which is in poor condition located on Rt.5 approximately 500' north of and across the street from the Armory, and currently used to store boxes of paper records. The site offers possibilities for addressing Museum needs, but the building does not appear to be worth anything but minimal maintenance investments to provide temporary storage of relatively light-weight materials. In addition to obvious security issues, rented storage off-site has the built-in risk of becoming unavailable in the future, which may incline the Museum towards building storage they own rather than renting it. However, the current off-site storage space at Cone-Blanchard in Windsor has the advantage of a forklift and operator on-site, and appears to be a stable resource for the present. The Museum is currently exploring options to generate some income from the site, through rented space for parking; it is also evaluating options to sell the site and use the funds in support of the current collection and buildings at the Armory site.

Collections Issues

While building conditions cited above obviously affect both the displayed and stored collections and the ability of Staff to work on them, additional building functional concerns include the need for more storage and work space, for better-defined and equipped spaces, and for support features (cabinets; shelving; sinks; janitorial support; kitchenette with sink for proper food handling and storage; lighting; light-controls at windows; etc.) to address human comfort and collections management requirements. Much of the material being stored is paper, including photographs, maps, etc. with fairly consistent requirements for temperature, humidity and ambient light controls, but the major volume of storage is non-archival; most of it is located in the 2nd floor of the east wing, and in an unconditioned adjacent storage room in the Armory. The other main category is metal machinery, which is stored on all levels of the Armory, as well as in off-site rented storage space.

The Staff have identified the need for additional on-site storage space – mainly involving paper artifacts. A new enclosed, conditioned and insulated space approximately 1/3 the size of a typical Armory floor (or about 1,300 s.f.) would be positioned at least 3' inside existing exterior walls, to allow access around the new construction for inspection and maintenance and to avoid condensation problems. The enclosure will likely not need to be relocated in the future, and would be most economically constructed on the third floor as a stick-built wall with dense-pack cellulose insulation. It should have a modest climate-control system (split system: heat-pump driven wall-mounted units in the space, w/ external pad-mounted condenser) to temper the space.

Accommodations are needed for staging appropriate and environmentally-friendly Museum events that include preparation of refreshments and clean-up, for managing a small Museum shop including ticket sales and supervision of visitors entering the building, for storing tables and chairs, and for maintaining a small office. This will entail some renovations to the 1st floor of the east wing, which should include a look at the current very-steep stairs to the offices, meeting room and library area on the 2nd floor, which are a safety concern as well as a convenience issue. These stairs appear to be historic, and will need careful consideration if they are to be altered; accessibility for the 2nd floor and upper floors of the Armory will only be achieved when a new elevator is eventually installed.

Specifics of climate control requirements and strategies for modifying or supplementing the current HVAC system are covered in detail in the accompanying reports from Conservator Rick Kerschner and Mechanical Engineer Dan Dupras. They are not expected to have any major

impacts on historic building fabric, structure or performance, and can be designed and installed in a manner that respects and defers to the appearance and interpretation of the 1846 Armory. The climate-tempering mechanical improvements can be implemented incrementally as suggested in the reports, allowing for feed-back from performance monitoring data and adjustments as needed. Experience will also yield accurate data on probable costs for subsequent additions to the system. Some tightening up of the existing historic envelope, consistent with good preservation practice, is needed to prepare for the new mechanical equipment and artifact storage areas.; this will involve re-pointing and masonry repairs, caulking at all masonry openings, conservation of windows, and weather-stripping of freight doors and interior openings between floors.

Shielding metal artifacts from sunlight is not required for most artifacts; based on Staff identification of the few pieces where this is needed, a method for screening will be used as re-location is not a practical option, at least for the larger pieces. The current use of the protective waxes should be continued.

Summary of Recommendations and Estimated Costs

A. Low-Cost Short-Term Improvements

1. Insulate pipes in Mechanical Room to reduce heat loss (estimated cost: \$75)
2. Install 3 paddle ceiling fans/floor in Armory- (9) total (estimated cost: \$4,500)
3. Purchase hand-held humidity monitor, light meter (estimated cost: \$1,100)
4. Purchase PEM loggers to replace Hobos (\$349. ea) (estimated cost: \$3,300)

B. General Recommendations from NEH-SCHC Study (w/estimated cost)

1. Continue monitoring of environmental conditions (PEM data loggers)
2. Establish system for monitoring the bow in Armory N and S walls (\$500-700)
3. Install sub-surface membrane gutters N & S sides of E wing; swale on W end; further investigation of E. wall @ E wing for water infiltration (\$21-24,000)
4. Tighten up Armory envelope – masonry repairs, pointing; window restoration, caulking; freight doors; openings between floors. (\$45,000-55,000)
5. Build insulated room-in-room on 3rd Fl. of Armory; incl. humidifier; track impacts (\$42,000-49,500)
6. New ASP smoke detection system and up-graded fire alarm panel, monitoring (\$35-40,000)
7. Isolate basement at 1st fl.; provide push/pull fans (2) for ventilation (\$42-46,000)
8. Install mini-split heating/cooling in Armory 1st floor, humidistatic controls (\$82-102,000); and provide improved shelving/cabinets etc. for new and existing storage (\$6-9,000)
9. Repair retaining wall at river (\$98-114,000)
10. Improvements to existing heating system (replace Modine fan-coil units w/baseboard, etc.); new Janitor's closet in basement (\$55,000-78,000)
11. Lobby renovations (\$27,000-35,000)
12. High-quality storms (30) on E wing (\$22,000-24,000)
13. Provide new elevator with access to all levels. (\$138,000-165,000)
14. Masonry restoration of exterior (probably phased) (\$1.2-1.4M)
15. Determine future of Annex site (N/C)
16. Add mini-split conditioning to 2nd and 3rd floors of Armory (\$125-154,000).

These are preliminary costs, to be adjusted as additional information becomes available, but they give a feel for the size of the undertaking, and the likely resources needed to carry them out. Architectural and engineering design is included in the estimated costs. Planning for a particular phase may involve completing some work from a number of the items listed above; wherever possible it should be planned to reach logical stopping points without need to un-do any substantial amount of previous repairs. In some cases, the difficulty and cost of access will make it important to cover all work in that area; experience and judgment will play an important role in addressing these opportunities economically and efficiently.

The amount of climate control infrastructure to be added can be phased in with appropriate pauses to evaluate the effects and the cost-to-benefit ratio. Storage and work space needs and type of materials accommodated are unlikely to vary significantly; adding these spaces may be able to be phased as well, to respond to available funding. Building and site improvements are generally once-and-done projects, but often have a maintenance component with attendant operating costs. Finally, all improvements – including plans for improvements – should be revisited periodically to update them and adjust for any new developments in the collection or changes in management policy and methods. HVAC and lighting technology will change significantly over 20-50 years while conservation methods for masonry and wood structures will not change much if at all.

Model Project Feedback

As the work recommended in this study is implemented, the Museum with assistance from the consulting team will evaluate the results, to develop a record of the improved conditions and to make any necessary adjustments to the systems and technology employed. Evaluation takes a minimum of a year, and often longer before meaningful data can be gathered; this is outside the time-frame of this Grant but data collection that began several years ago with the Hobo data loggers will continue, supplemented by new information from each of the recommended steps, and this process will continue as part of the stewardship of the building and collection. Short-term improvements can be achieved in the next 6-12 months; recommendations #1-4 to prepare the building for the major improvements can occur over a period of a year to 18 months, with items #5-7 following in the next 1-2 years using grant funding that will be applied for in the next six months. The remaining items are likely to be spread out over the next 3-6 years, and will be responsive to grant funding opportunities and donations. It would be most efficient to do all of them at once, as a single project if this were possible.

With a website already established (www.pemdata.org) and several years of data accessible there, the Museum is well set up to go forward, using good standards and metrics to inform the quantitative data reported. The feedback will allow other institutions studying the measures employed by the American Precision Museum to build on APM's successes, and learn from this experience how to fine-tune their efforts at conserving and extending the life of their collections.

A Note on Monitoring of Armory N and S Walls

To begin developing data on possible changes in the condition of these walls, it will be necessary to establish a benchmark from which to measure. This can be done by selecting and clearly identifying end-points of a straight line running parallel to the wall and close to it - it can be a string, or a small laser light-beam, but what's critical is to establish a procedure that will give us exactly the same line each time it is set up. It could be an iron rod driven next to the end

walls (the 'returns' at the E wing and stair tower) for the South wall, with a notch in the top, coupled with photos and sketch/measurements/diagram to make sure it remains stationary over time. Relating it to a specific brick or mortar joint on the return walls will help. (The North wall could be either interior or exterior)

With the straight line established, measurements from the line to the wall at center and at several intermediate points (e.g. under certain windows; but the same spot each time) which are then recorded in a simple chart will show whether there is any change to the distances. We are looking for trends more than exact dimensions...it's more important to know that there is an approximately 1/8" change than to know that it's 0.12497".

Ideally the tools to monitor are stored together indoors and clearly marked, not used for anything else, and findings are recorded consistently in a notebook clearly identified for this purpose and kept in the same, safe place except when doing active monitoring. Be sure to log and date results consistently; establish dates to monitor (2x/year in Spring and Fall, is enough). When monitoring, observe the wall and record/photograph any visible changes (cracks; pieces of brick or stone on ground; displacement of masonry units; etc.) along with the measurements. Be sure to inform architect of any changes noted.

Monitoring needs to become part of the routine for managing this resource, and should be institutionalized so that it is not dependent on any single person, or unable to proceed in their absence.

Conclusion

The APM has done a tremendous amount to organize, catalog, conserve, protect and interpret their unique collection, including the Armory itself; while the conservation of the building is on-going, this appears to be an appropriate time to invest in the improvements to collections storage and handling that are outlined here. The effects of a small but dedicated and skilled staff can be leveraged very effectively with these improvements, and the long-term impact on the mission of the APM will be significant and lasting. While it is a constant balance between competing needs of the building, collection and programs for the public, all will benefit from the improvements recommended here.

Code compliance needs to be phased in along with other improvements, and funding will also be needed for repairs to the retaining wall at the river, for special projects like the Landscaping work, and for continuing maintenance of the building and improvements that have already been installed. Providing the right storage, exhibition and work space with sensible but not complicated environmental controls, and the facilities for functional human comfort of Staff and visitors will ensure the long-term viability of the institution.

We are pleased to have the opportunity to assist you in the stewardship of this unusual and significant building and collection; implementation of the recommended measures will be a major step to improve its security and longevity. We hope this study will assist you in prioritizing and carrying out these changes, and we look forward to participating in the evaluation of these steps as they are implemented. The preservation of this significant collection of resources is amply justified by the wealth of information about an historic period of technological progress embodied in the collection; these steps should not only afford greater security and protection of this resource, but should also provide a valuable template for similar collections elsewhere.

Prepared by: _____TFK_____

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HVAC SYSTEMS REPORT

FOR

CONSERVING THE COLLECTION

AT THE

AMERICAN PRECISION MUSEUM
WINDSOR, VERMONT

MARCH 2011

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HVAC Systems Report for the Conserving the Collection

A. SCOPE AND PURPOSE

We have toured the building with the director and all consultants and have attended a meeting to discuss the NEH – SCHC Planning Grant on December 16, 2010. At this meeting we discussed the short and long term plans as well as the methods to improve the environmental conditions for the collections housed at the American Precision Museum Armory building. This report outlines our recommendations as it relates to providing HVAC systems to achieve these goals.

Richard L. Kerschner, the conservation consultant, has prepared a report which has identified the environmental (temperature and humidity) goals for exhibit, storage and archive storage areas. This report has provided practical recommendations for improving the environmental conditions for the collections while being considerate to the limitations of this historic structure.

The recommendations for the HVAC systems will be based on the environmental and system recommendations described in Mr. Kerschner's report.

B. EXISTING CONDITIONS

The original armory building is an historic mill structure built in 1846; it is a 3 ½ story structure with masonry load bearing exterior walls. The building has over 150 single pane windows. The original armory building has a dirt floor basement which originally housed the water wheel which powered the original mill. The basement has a dirt floor which contributes a significant moisture load to the floors above. The armory structure is currently unheated and is being used for storage of artifacts and related materials. The ground floor of this structure is used to house exhibition space.

Attached to the original mill structure on the east side is a two story building called the East Wing. This part of the building is heated and is used for museum offices and artifact storage on the second floor. The first floor is used to house exhibitions. The boiler serving this area of the building is a high efficiency, sealed combustion LP gas, Triangle-Tube boiler which was installed in 2008, this boiler appears to be in good repair and is adequate for the current connected heating load. This boiler system does not have the capacity to heat other areas of the building. The heating piping in the boiler room is un-insulated and should be insulated to improve system efficiency.

C. HVAC CONSIDERATIONS TO ADDRESS PROPOSED ENVIRONMENTAL IMPROVEMENT ACTIONS

General: The recommended environmental improvements described in Mr. Kerschner's report are focused on preservation of the collections. The environmental requirements for the collections and occupant comfort are very different. Mr.

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Kerschner's recommendations are designed to control of humidity in the summer months and raise the temperature in the winter months to reduce the space relative humidity, to limit the extreme and swings in indoor humidity. HVAC systems which provide both occupant comfort and satisfy environmental considerations for collections can only be achieved when the building envelope is designed and the HVAC are sized to accommodate these requirements. This would not be possible in this building unless new insulated spaces where constructed within the existing building envelope. Additionally, the type of HVAC system required to maintain these conditions would be very expensive to install and very costly to operate. In this report, we have included an analysis of operating cost and energy usage for the proposed system versus the ideal system.

Armory Basement: As stated in Mr. Kerschner's report, the basement area is very moist and is subject to ground water infiltration, which cannot be reasonably renovated to make it useable for storage of collections. Mr. Kerschner has recommended isolating this area form the upper floors to mitigate moisture infiltration to the upper levels of the building. I concur with this recommendation as it will improve the effectiveness of the proposed HVAC systems on the floors above and would reduce long term operating costs for the mechanical systems. We recommend that this area be ventilated using outdoor air when the outdoor air enthalpy is less than indoor conditions. A push-pull supply and exhaust system is recommended which would be sized to maintain a slightly negative condition in the basement.

(Definition of Enthalpy: Enthalpy is generally defined as to the total energy in the air, in other words the outdoor temperature and humidity conditions would have to be such that the introduction of this air would not cause condensation on cold surfaces in the basement.)

Exhibition and Collections: As stated in Mr. Kerschner's report the ideal environment for exhibition and collection storage would be 68 deg. F. plus or minus 3 deg. F. with relative humidity (RH) at 50%, plus or minus 5%. This environment would also be good for occupant comfort. However, the historic building envelope will not allow these conditions to be maintained, because condensation would form on the windows and masonry walls, which would encourage mold growth and would cause accelerated deterioration of the structure and finishes. Given these issues, Mr. Kerschner's report provides practical recommendations to limit the humidity swings between 70% RH and 25% RH, with a summer maximum temperature of 75 deg. F and minimum winter temperature of 35 deg. F. This range of temperatures will not allow for thermal comfort suitable for year round occupancy of the building. Since it is our understanding that the museum is closed from November through May this should not present a problem.

Archival Storage: As stated in Mr. Kerschner's report, Archival storage space will require a lower RH maintained at a RH of 45-50% RH. This level of humidity control

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would require construction of an insulated environmentally controlled room within the existing historic building envelope. Mr. Kerschner's report provides practical methods to achieve this level of control. However, it is important to note that with this approach, the winter temperatures would not be maintained within acceptable ranges for occupant comfort.

Office and Library: These spaces are currently heated and cooled for occupant comfort. Although the existing heating system provided adequate heat, the systems do not provide proper zoning and acoustical levels. The existing heating system should be re-zoned and revised to include a zoned baseboard radiation system, which will eliminate noisy fan heaters and effectively heat this area. Permanent cooling systems should also be provided to improve efficiency and provide proper cooling capacity.

D. HVAC RECOMMENDATIONS AND ESTIMATED CONSTRUCTION COSTS

General: Based on Mr. Kerschner's report, we recommend utilizing ductless mini-split HVAC systems to provide cooling and heating for this building. These systems offer many advantages to traditional systems which are very well outlined in Mr. Kerschner's report. These systems allow the HVAC system to be built incrementally, which will allow the systems to be phased and evaluated for their effectiveness. It is our understanding that these systems would be installed on the first, second and third floors and that the fourth floor would remain unconditioned.

HVAC Priority No. 1-Paddle Fans: It is our understanding that the first HVAC priority will be to provide paddle fans on the first, second and third floor of the Armory Building to keep the air moving , according to Mr. Kerschner this would deter the potential for condensation to form on the artifacts.

The estimated installation cost for this system would be:

Fans \$3,000

Wiring \$1,000

Engineering \$500

Total \$4,500

HVAC Priority No. 2: The second HVAC priority consists of three components. These include a ventilation system for the basement, HVAC control for the first floor exhibition space and finally construction of a room on the third floor to house archives.

Basement: We recommend installation of a push-pull ventilation system which would allow outdoor air to provide ventilation of this area when the enthalpy of the outdoor air is less than indoors.

The estimated installation cost for this system would be:

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Fans	\$5,000
Wiring	\$1,000
Estimated Engineering Cost	\$1,000
Total	\$7,000

First Floor Armory Space: For the first floor armory exhibit space we estimate that this area would require a cooling system with a capacity of 5-7 tons of cooling. The sizing of this system is based on maintaining the conditioned space at approximately 25 degrees F during the heating season. We estimate that the required heating capacity to maintain this area at 25 deg. F. the heating capacity would be approximately 110,000 BTUH. We recommend using a Mitsubishi Hyper-Heat air source heat pump system model PUHY-HP96THMU-A. This system will provide a nominal 8 tons of cooling capacity and 108,000 BTUH of heating capacity at -13 deg. F outdoor air temperature. This system would include four indoor wall mounted evaporators which could be staged to maintain the required conditions. It should be noted that this system will not provide heating if the outdoor air temperature drops below -25 deg. F. If reliable heating was required year round, expansion of the existing hot water heating system, or additional fuel fired equipment would be required to provide a back-up heating system, this would be costly operate and cost prohibitive to install.

In order to properly control the humidity in the conditioned areas we recommend installing a Direct Digital Control system using Viasala humidity sensors. This system can be integrated with the recommended HVAC system controls. This system will also prove to be effective for monitoring of the building humidity and temperature trends.

In order, to accommodate these recommendations we estimate that a new 3 phase, 400 Amp electrical service would be required. We recommend sizing the service to accommodate the full build-out of the HVAC system to serve all floors.

The estimated installation cost for this system would be in the range of:

HVAC System	\$45,000-\$55,000
DDC Controls	\$12,000-\$15,000
Electrical Work	\$15,000-\$20,000
Estimated Engineering Cost	\$7,200-\$9,000
Total Estimated Cost	\$79,200-\$99,000

Note: This system will require an annual service contract with a qualified HVAC company to maintain the equipment and controls. We estimate the annual service contract would be \$4,000-\$5,000.

Third Floor Archive Space: The construction of a 1,300 square foot insulated

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“room within a room” on the third floor would require a separate HVAC system to maintain the required environmental conditions described in Rick Kerschner’s report. We recommend installation of a vapor retarder system around the entire room to allow for proper control of humidity in this room. We estimate that the required heating capacity for this room would be approximately 16,000 BTUH and the required cooling for this room would be 0.75 tons of cooling. As recommended in Mr. Kerschner’s report a commercial dehumidifier would be required to supplement the dehumidification requirements of the HVAC system.

This area will also require Viasala humidity sensors with DDC controls.

The estimated installation cost for this system would be in the range of:

HVAC System	\$8,000-\$10,000.
DDC Controls	\$2,000-\$2,500
Electrical Work	\$1,500-\$2,000
Estimated Engineering Cost	\$1,150-\$1,450
Total Estimated Cost	\$12,650-\$15,950

HVAC Priority No. 3- HVAC system for the Second Floor: We estimate that the second floor would require a system similar to the first floor system described above. We anticipate that the same environmental strategies would be employed.

The estimated installation cost for this system would be in the range of: HVAC

System	\$45,000-\$55,000
DDC Controls	\$8,000-\$11,000
Electrical Work	\$3,000-\$5,000
Estimated Engineering Cost	\$5,600-\$7,100
Total Estimated Cost	\$61,600-\$78,100

HVAC Priority No. 4- Complete the HVAC for the Third Floor: We estimate that the third floor would require a system similar to the first floor system described above. We anticipate that the same environmental strategies would be employed.

The estimated installation cost for this system would be in the range of:

HVAC System	\$30,000-\$35,000
DDC Controls	\$5,000-\$8,000
Electrical Work	\$2,000-\$3,000
Estimated Engineering Cost	\$3,700-\$4,600
Total Estimated Cost	\$40,700-\$50,600

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HVAC Priority No. 5- East Wing Building Office and Library HVAC Improvements: In this area, we recommend installing a permanent air conditioning system which would provide more effective and efficient cooling and controls. We recommend that the remove the existing fan coil units and replace zoned baseboard hot water heating units and zone controls be retrofit to provide a quiet and effectively zoned system. The existing gas boiler would remain to serve the same loads.

The estimated installation cost for this system would be in the range of:

Heating System Work	\$10,000-\$15,000
Permanent AC System	\$20,000-\$30,000
DDC Controls	\$5,000-\$8,000
Electrical Work	\$3,000-\$5,000
Estimated Engineering Cost	\$3,800-\$5,800
Total Estimated Cost	\$41,800-\$63,800

E. ANTICIPATED OPERATIONAL COSTS

The proposed HVAC systems included in this report will result in additional operational cost. Even though the proposed recommendations would result in a building which is minimally conditioned, the operational costs will be significant primary because of the lack of insulation and efficient windows.

We estimate that it will cost approximately \$2,500 per floor per year to operate the proposed HVAC systems. So, if the first second and third floors are conditioned we estimate the annual electric costs would be approximately \$7,500 per year. This operational cost is based on electrical cost of \$0.12/kwh and temperature and humidity set points as defined in Mr. Kerschner's report. Propane heating costs are anticipated to remain unchanged as the new areas would be heated using the electric heat pumps.

F. COMPARISON OF OPERATIONAL COSTS AND ENERGY USAGE FOR THE PROPOSED SYSTEM VERSUS AN IDEAL SYSTEM:

As part of this report we analyzed the energy usage and operating costs for the proposed HVAC systems, versus a system which would maintain ideal conditions for exhibition and collection storage at 68 deg. F. plus or minus 3 deg. F. with relative humidity (RH) at 50%, plus or minus 5%. This is based on one floor.

The results of this of the operating cost are shown in the Table 1 below:

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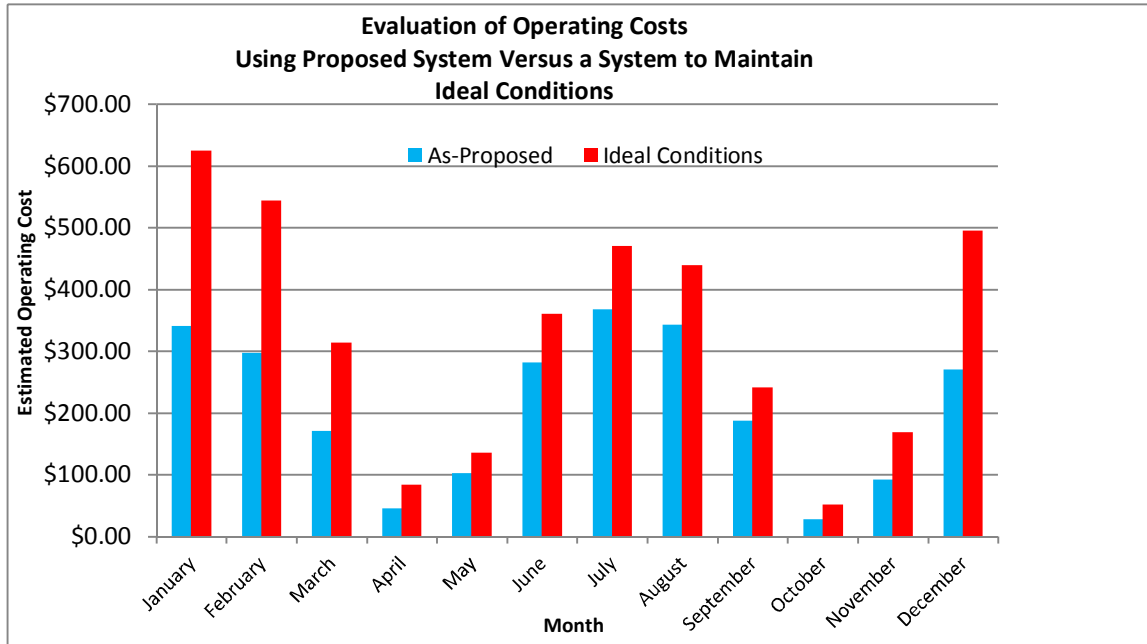


TABLE 1 - Operating Cost comparison of an ideal HVAC system versus Recommended Systems (Analysis is for one floor, other will be similar)

The results of this of the energy usage are shown in the table 2 below:

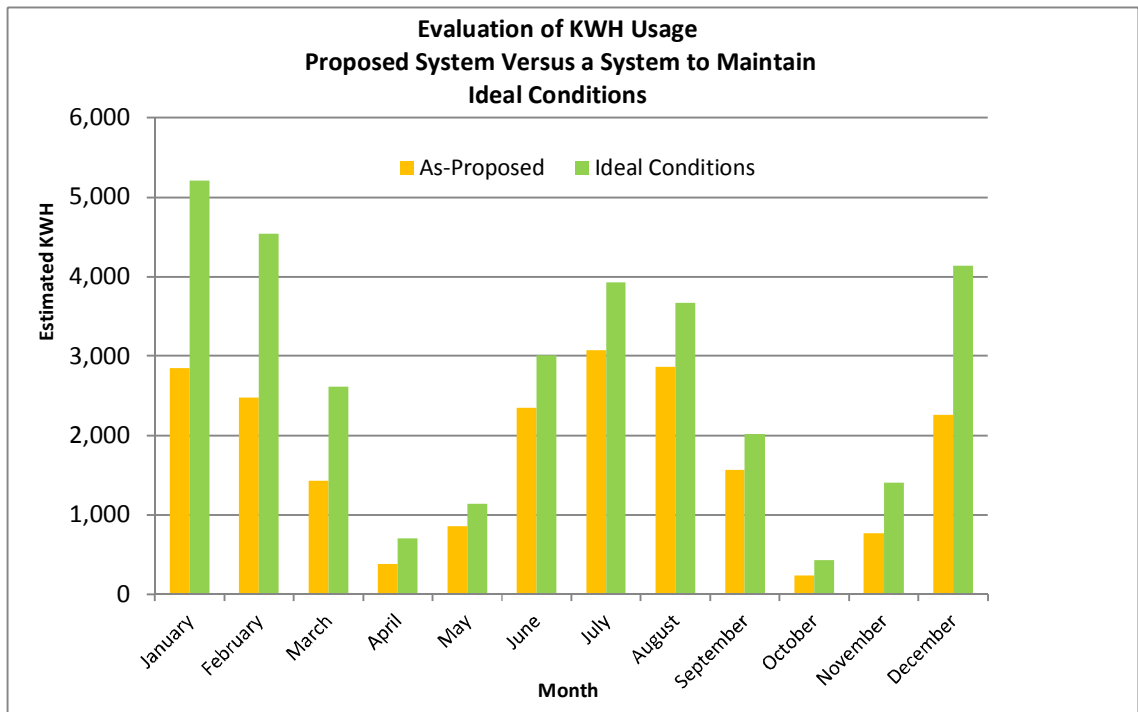


TABLE 2 – Energy Usage comparison of an ideal HVAC system versus Recommended Systems (Analysis is for one floor, others will be similar)

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G. SUMMARY

The primary focus of this report was to identify the required HVAC systems required to address the environmental requirements to preserve the collections and archives at the American Precision Museum. The historic structure offers some unique challenges as it relates to these environmental considerations that must be balanced against the building limitations, to arrive at a solution which is both practical and feasible.

In our opinion, the recommendations presented in Mr. Kerschner's report are excellent and balance both the building limitations and the requirements of the collections.

The energy analysis shown above show that the recommended HVAC systems included in this report will significantly improve the environment for the artifacts while reducing the operating costs when compared to a HVAC system which would maintain ideal conditions. In our opinion, the recommendations presented in Mr. Kerschner's report are excellent and balance both the building limitations and the requirements of the collections.

It should be noted that the installation costs and long term operational costs are affected by the limitations of the existing historic building envelop. If this collection was housed in an envelope which was properly insulated, the size, operational and installation costs of the HVAC systems could be significantly reduced.